RF system upgrade - Overview

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Feb. 16, 2004
KEKB review committee

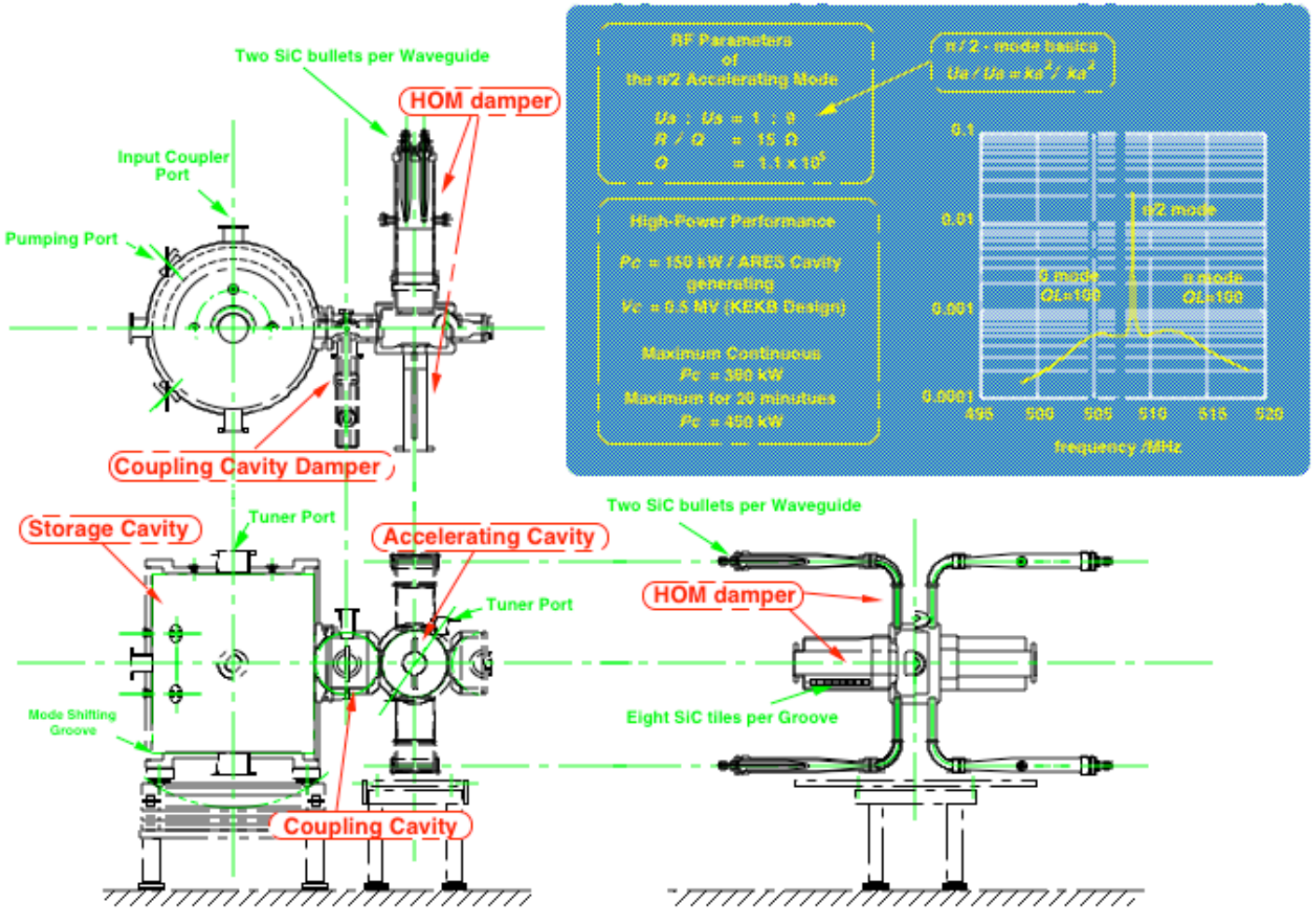
Contents:

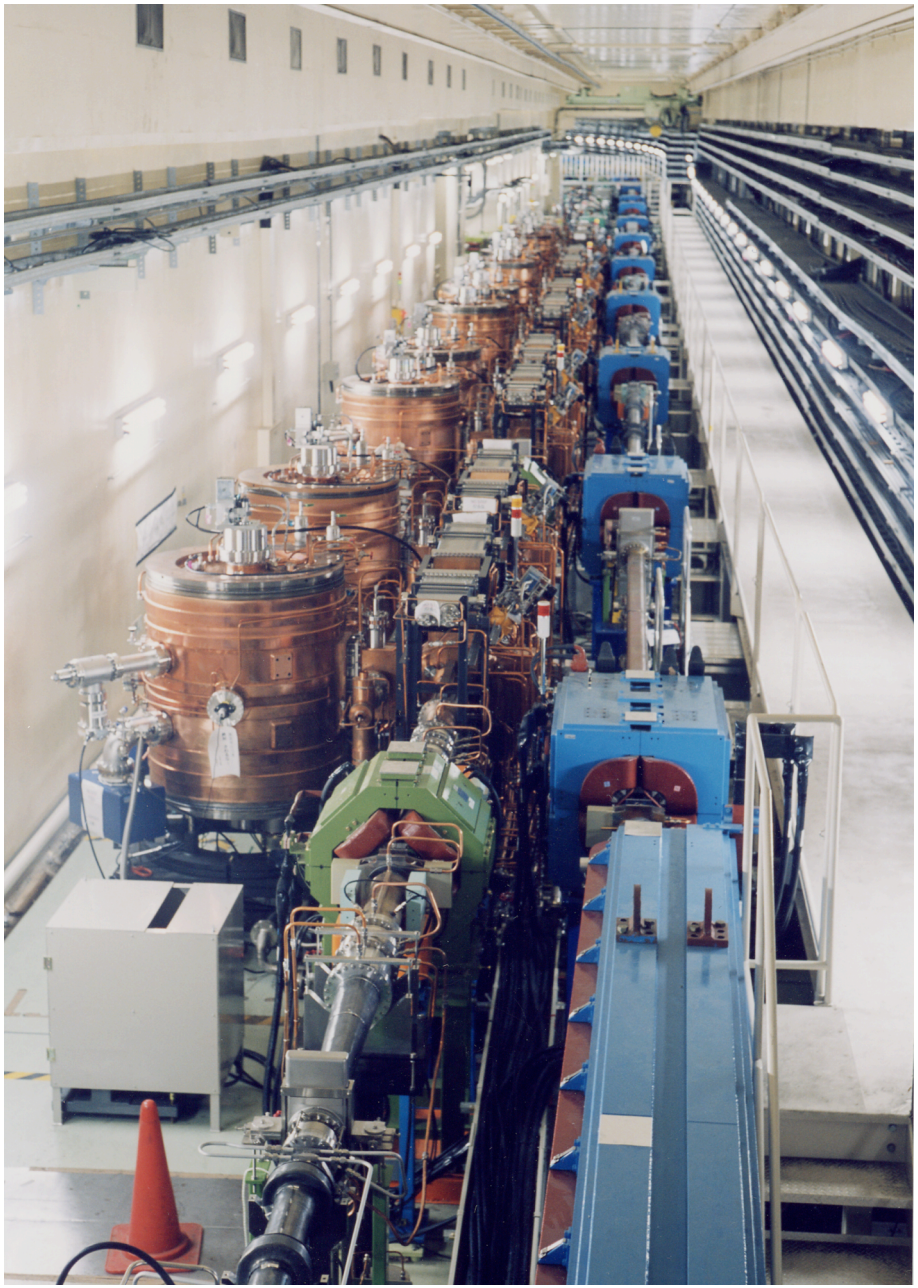
- **Base plan**
- **High beam current and measures**
- **Construction**
- **Summary**

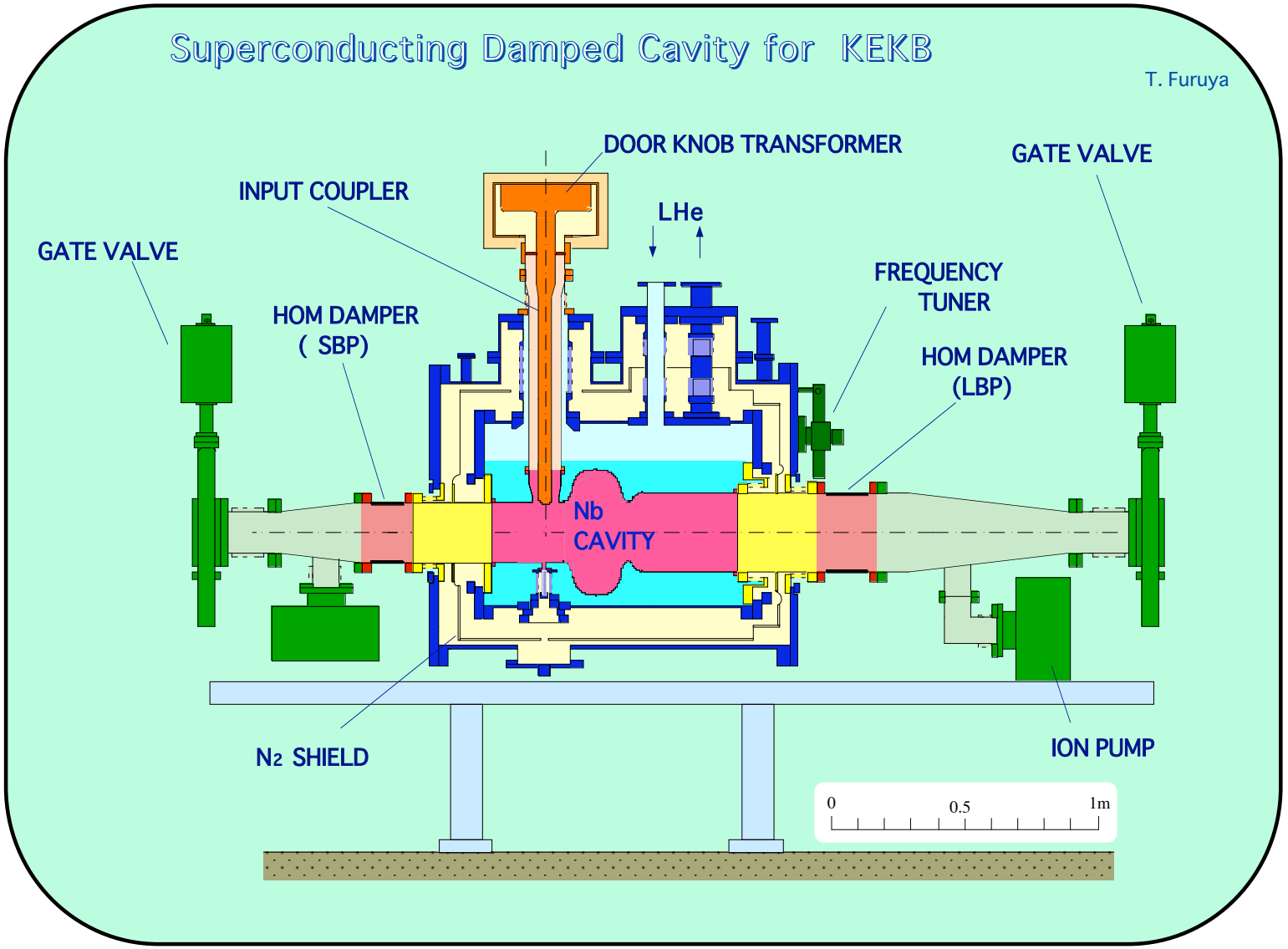
Base plan

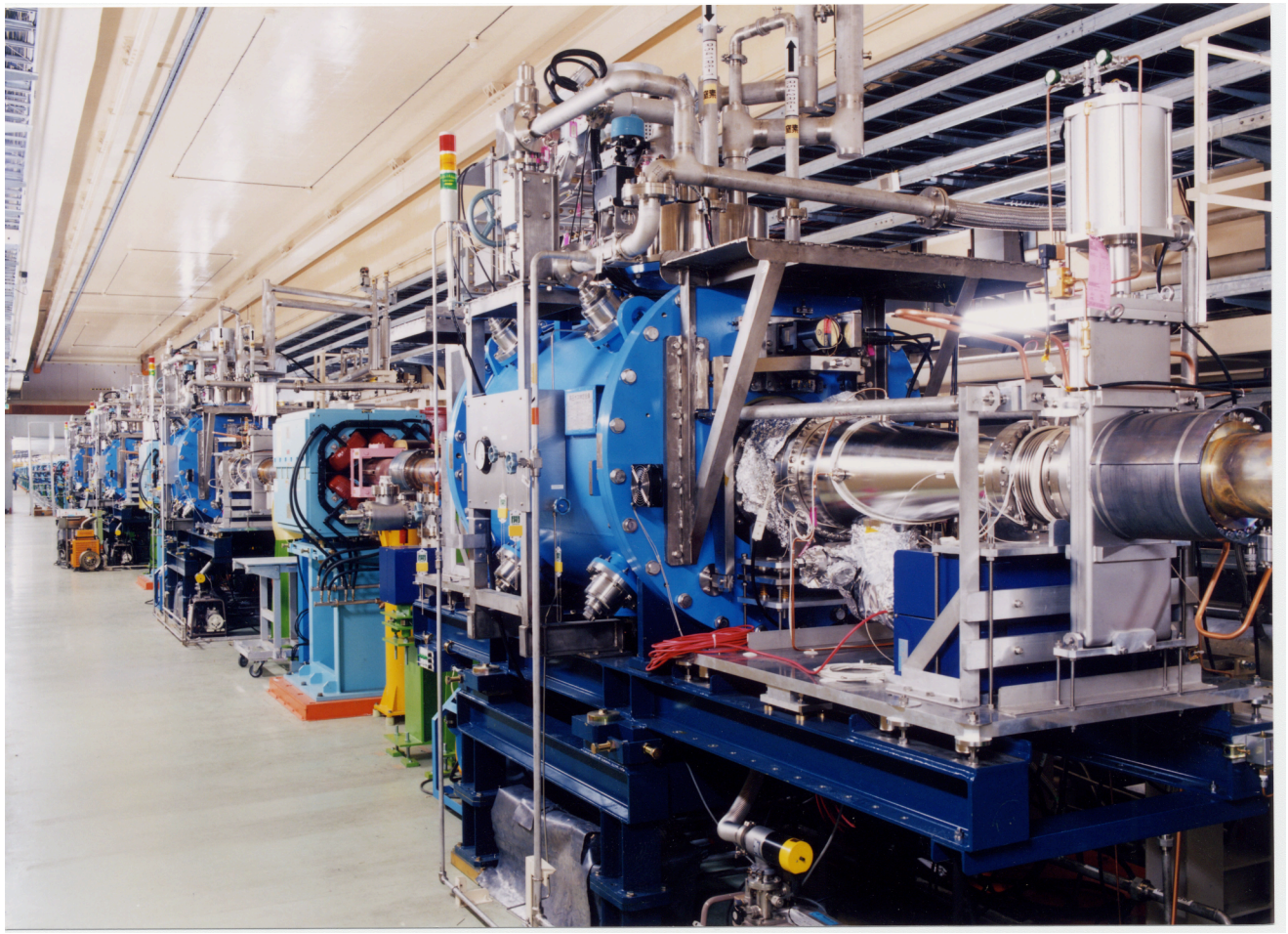
- **KEKB RF system**
  - **Excellent performance at 1.8A (LER) and 1.2A (HER) shows potential for operating beyond the design beam current of KEKB.**
- **Strategy for SuperKEKB:**
  - **Adopt the same RF frequency as KEKB and use the existing RF system as much as possible, with improvements as necessary to meet the requirements for SuperKEKB.**
- **If this scheme is feasible:**
  - **Construction cost is greatly reduced.**
  - **Technical uncertainties are relatively small.**
- **Possible problems to be investigated:**
  - **Issues related to very high beam current (4 times as KEKB)**
  - **Short bunch length of 3mm.**

The ARES cavity






Superconducting Damped Cavity for KEKB
T. Furuya
DOOR KNOB TRANSFORMER
GATE VALVE
INPUT COUPLER
LHe
GATE VALVE
FREQUENCY TUNER
HOM DAMPER (SBP)
HOM DAMPER (LBP)
Nb CAVITY
N2 SHIELD
ION PUMP
0
0.5
1m



RF parameters

Ring	LER	HER		
Beam current (A)	9.4	4.1		
Wiggler magnets	yes (half)	no		
Energy loss/turn (MeV)	1.2	3.5		
Loss factor, estimated (V/pC)	40	50		
Radiation loss power (MW)	11.3	14.3		
Parasitic loss power (MW)	7.1	1.7		
Total beam power (MW)	18.4	16.0		
Total RF voltage (MV)	14	23		
				(Total)
Cavity type	ARES	ARES	SCC	ARES / SCC
No. of cavities	28	16	12	44 / 12
Voltage /cav. (MV)	0.5	0.5	1.3	
Loaded-Q value (x10E4)	2.4	2.4	4.0	
Beam power /cav. (kW)	650	650	460	
Wall loss /cav. (kW)	233	150	-	
Detuning frequency (kHz)	45	31	74	
Klystron power (kW)	930	850	480	
No. of klystrons	28	16	12	56
Total AC plug power (MW)	40	23	10	73

Issues to be solved

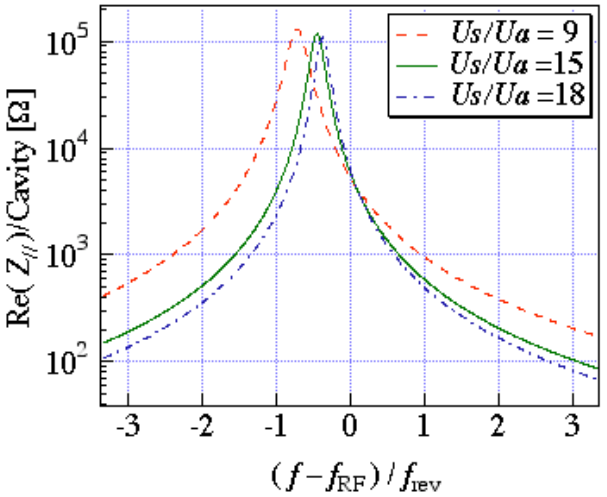
- **Strong longitudinal CBI due to a large detuning, even with ARES and/or SCC.**
  - **Growth rate = $(0.3\ \mathrm{ms})^{-1}$**
- **CBI due to HOM and other parasitic modes**
- **Large HOM power in each cavity**
  - **HOM dampers**
- **Strengthening of RF power is required**
  - **4 times as high as KEKB**

Measures for the fundamental mode instability

- **Modify LER-ARES**
  - **Remodel the A-C cavity of the ARES to increase the stored energy further.**
  - **The growth rate is then reduced from $(0.3\text{ms})^{-1}$ to $(1.6\text{ms})^{-1}$.**
  - **This modification will not be used on the HER-ARES (majority of the driving impedance is attributed to SCC).**
- **Powerful feedback using a comb filter**
  - **The growth time of 1.6ms (LER) and 1ms (HER) is faster than the radiation damping time by a factor of 20.**
  - **Further study to test the performance limit of existing -1 mode damper in KEKB and the R&D to improve the performance, if necessary, will continue.**
  - **The -2 mode damper will be added.**

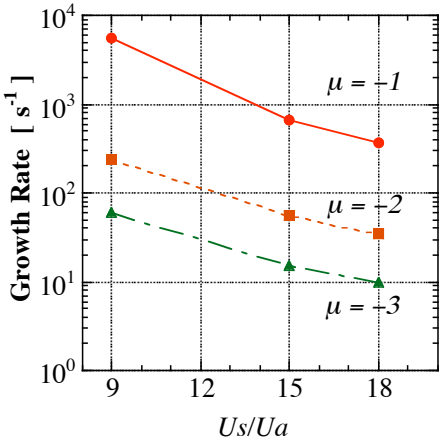
Modification of LER-ARES

- **The ARES in LER will be remodeled to increase the stored energy further.**
- **By enlarging the coupling hole between A-C cavities, Us/Ua will be increased from 9 to 15.**



T. Kageyama, et. al. **Coupling impedance for the p/2 mode**

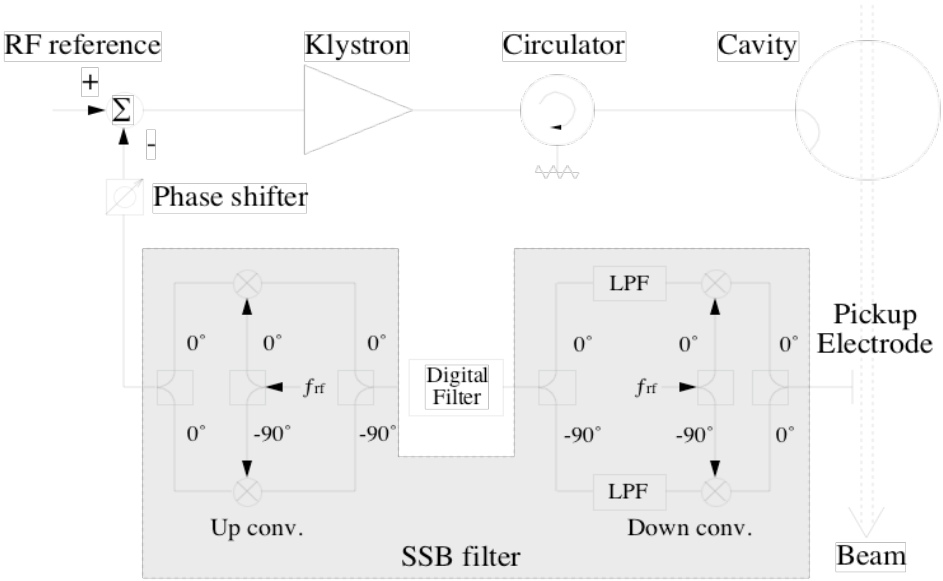
	exsisting	modified
Energy ratio	1:9	1:15
Detuning (kHz)	65	45
Growth time (ms)	0.3	1.6
C-damper (kW)	41	26

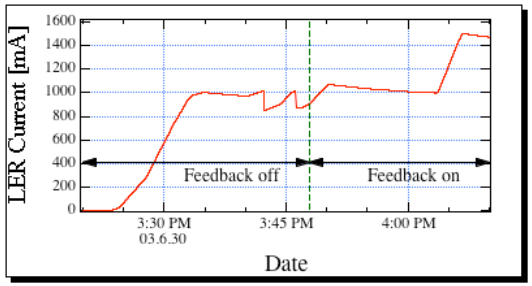


Growth rate as a function of Us/Ua

The existing -1 mode damper at KEKB

- **The -1 mode CBI occurs at more than 1A in KEKB-LER.**
- **It is suppressed by the -1 mode damper.**
- **The damping time of 1 ms is required for SuperKEKB.**





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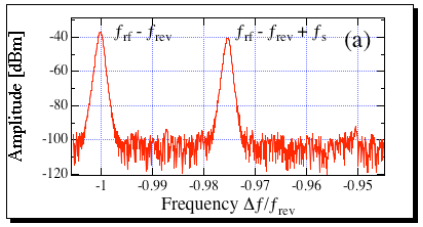

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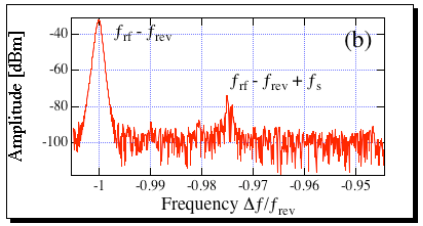
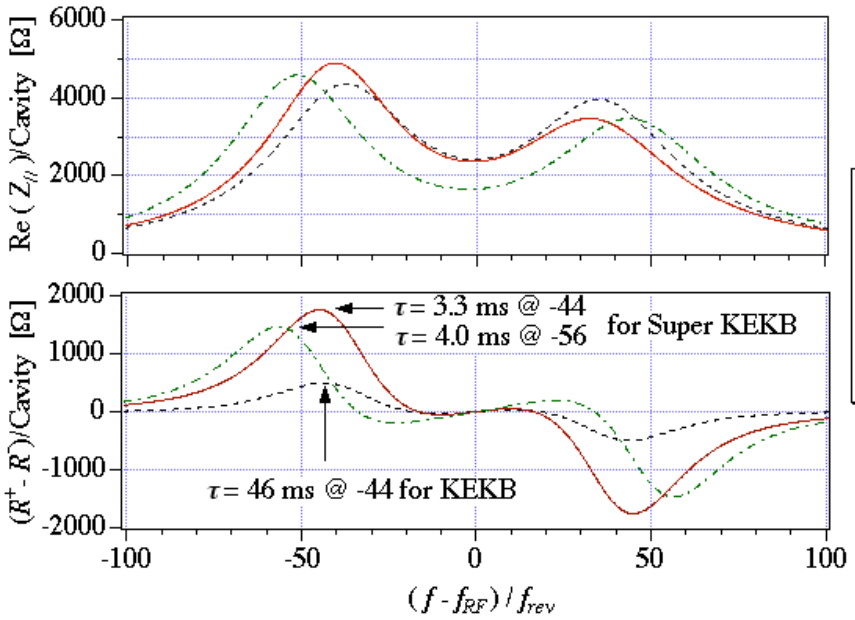
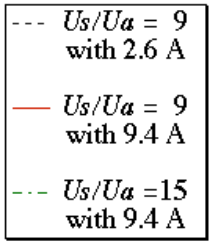


S. Yoshimoto, et. al.

CBI due to the 0 and π modes of ARES



Top:
Re [Z//] of the 0 and π modes



Bottom:
Re [Z//] imbalance R+-R-

- **The large detuning of the A-cavity gives rise to imbalance of the 0 and π mode impedance.**
- **Longitudinal CBI can be excited. The growth time is 4ms.**
- **It is outside the bandwidth of the klystrons.**

Summary of CBI due to RF cavities

Longitudinal

Item	Freq. (MHz)	LER		HER		Cure
		# cav.	Growth time	# cav.	Growth time	
ARES-HOM	1850	28	5ms	16	47ms	B-B
SCC-HOM	1020		-	12	49ms	B-B
Crab-HOM and LFM	655	2	41ms	2	214ms	B-B
ARES - 0/pi modes	504	28	4ms	16	29ms	B-B
Fundamental –1 mode	508.79	28	1.6ms	16+12	1ms	RF
Fundamental –2 mode	508.69	28	20ms	16+12	21ms	RF

Longitudinal bunch-by-bunch FB is needed. Required damping time is 4ms.

Transverse

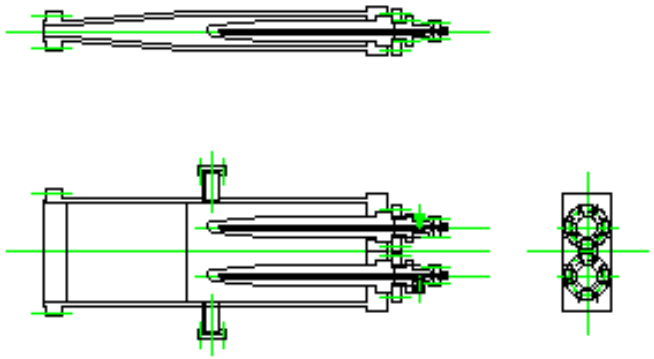
Item	Freq. (MHz)	LER		HER		Cure
		# cav.	Growth time	# cav.	Growth time	
ARES-HOM	633	28	4ms	16	33ms	B-B
SCC-HOM	688/705		-	12	12ms	B-B
Crab-HOM	773	2	4ms	2	12ms	B-B

The instability can be suppressed by the present transverse bunch-by-bunch FB.

ARES HOM dampers

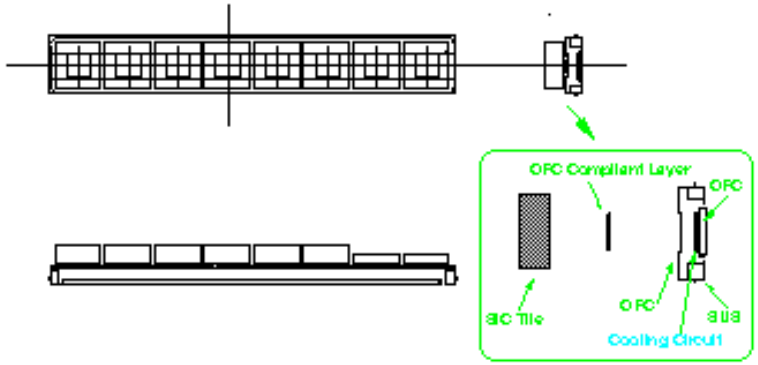
HOM LOADS

Bullet-shape sintered SiC Ceramic Absorber



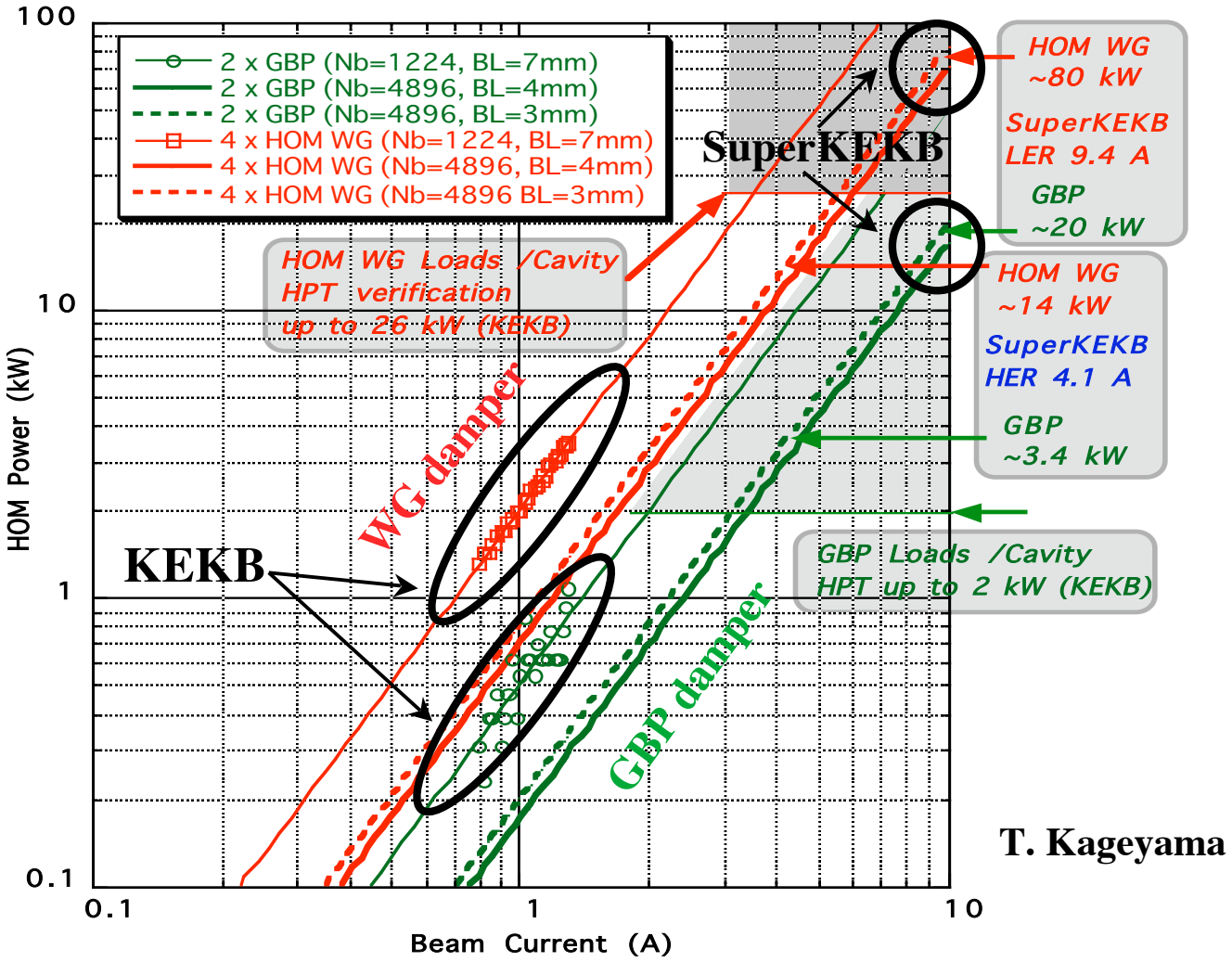
- Two absorbers (ø55mm x 400mm) per HOM waveguide.
- Power capability tested up to 3.3 kW (CW) per absorber.

SiC Ceramic Tiles for GBP HOM Load



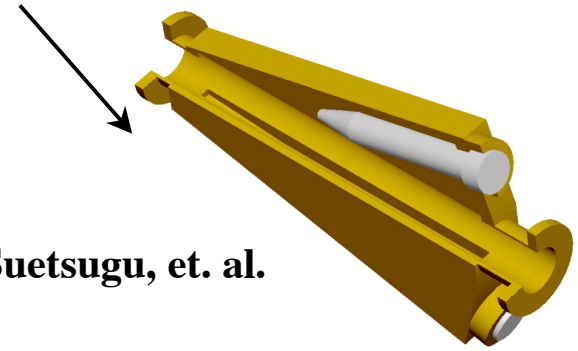
- Eight SiC tiles (48mm x 48mm x 20mm, or 10mm) per groove.
- Power capability upgraded up to 0.5 kW by brazing tiles to a copper plate cooled by water.

HOM power of LER-ARES



Improve the ARES-HOM dampers

- **The waveguide dampers**
  - **High power tested up to 3.3 kW/bullet (26 kW/cavity).**
  - **Upgrade needed to 80 kW/cavity.**
  - **Will be tested at higher power with a new high power source.**
  - **The number of bullets/waveguide will be increased.**
- **The grooved beam pipe dampers**
  - **High power tested up to 0.5 kW/groove (2 kW/cavity).**
  - **Upgrade needed to 20 kW/cavity.**
  - **A new type of damper? Such as a winged chamber with SiC bullets.**



Y. Suetsugu, et. al.

SCC HOM power and beam pipe

Beam pipe diameter	**150 mm (present)**	**220 mm (enlarged)**
Loss factor for 3mm bunch (Furuya)	**2.46 V/pC**	**1.69 V/pC**
HOM power for 4.1A, 5000 bunches	**83 kW/cavity**	**57 kW/cavity**
Influence to other groups	**No change**	**Replace chambers** **Large bore magnets** **Develop gate valves**

- **Present HOM dampers in KEKB have been operated up to 12 kW/cavity.**

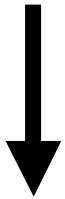
Improve the SCC-HOM damper

- **The present HOM damper will be bench tested to see its performance limit.**
- **The point is effective cooling, surface temperature, and outgassing.**
- **If SBP side damper works at 20kW, the present dampers may be used for Super-KEKB. If not, modification or new design of dampers is necessary.**

- **In addition, the beam pipe diameter will be changed to 220 mm to reduce the loss factor.**

Strengthening of RF power

- **Required RF power provided to beam is 18 MW (LER) and 16 MW (HER), four times as high as those of KEKB.**
- **The required RF voltage is relatively low.**
- **The number of cavities should be kept as small as possible to reduce the total impedance in the ring.**



- **Change to one ARES/klystron configuration.**
  - **KEKB: two ARES/one klystron**
- **The input power to each cavity will be nearly doubled.**
- **The number of klystrons will be more than doubled.**

Loss factor and Number of RF units

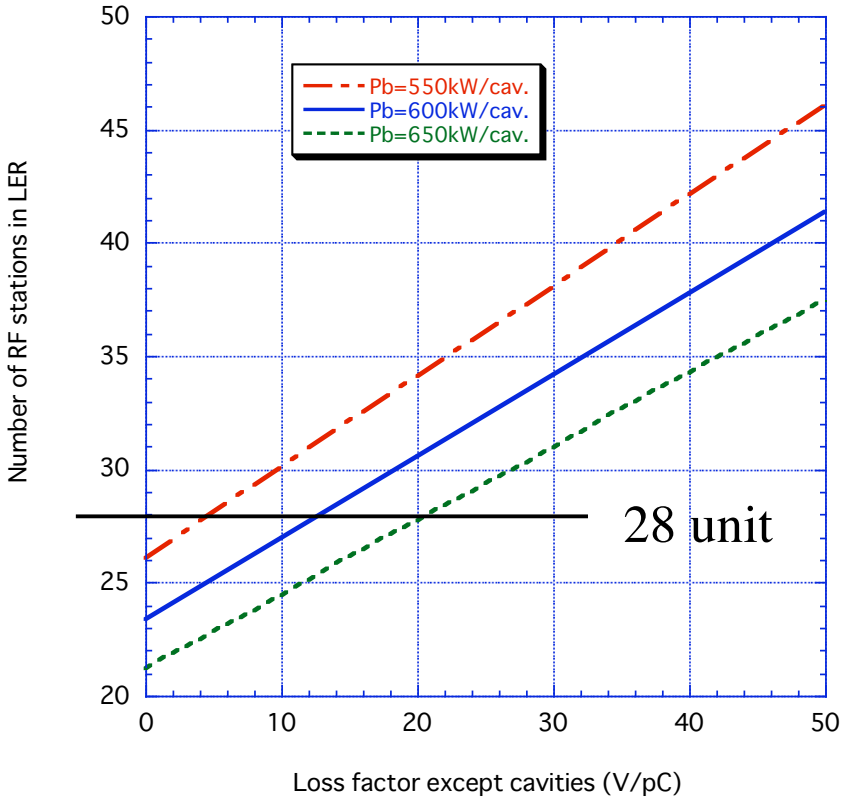
- **Required number of RF units is expressed as:**

$$N_{cav} = \frac{U_0 I_b + T_b k_{others} I_b^2}{P_{b0} - T_b k_{cav} I_b^2}$$

$$T_b = 1.965 \times 10^{-9} (s)$$
$$I_b = 9.4 (A)$$
$$U_0 = 1.2 \times 10^6 (V)$$
$$k_{cav} = 0.67 \times 10^{12} (V/C)$$

$$N_{cav} = \frac{11.3 + 0.174 \times k_{others}(V/pC)}{P_{b0}(MW) - 0.117}$$

k_{others} is loss factor except cavities, and
P_{bo} is beam power by each unit.



Input couplers

- **Performance at KEKB**
  - **Operating typically at 300-350 kW/coupler.**
  - **The ARES coupler tested up to 950 kW (through).**
  - **The SCC coupler tested up to 800 kW (through), 300 kW (total reflection).**
- **Requirement for SuperKEKB**
  - **Operation at 900 kW/coupler (ARES), 500 kW/coupler (SCC).**
- **Plans**
  - **A new high power test setup.**
  - **R&D to suppress multipactoring (TiN coating).**

Number of RF units

		KEKB		SuperKEKB	
		LER	HER	LER	HER
Oho	D4		3		14
	D5		3	8	2
Fuji	D7	5		10	
	D8	5		10	
Nikko	D10		4		6
	D11		4		6
Total		24		56	

New buildings needed

	Building for Power Supply (hight=5m)	Control room	Schedule
D4	455 m^2 (35m×13m)	170 m^2	2005～06
D5	-	-	
D7	273 m^2 (21m×13m)	100 m^2	2005～06
D8	304 m^2 (16m×13m+12m×8m)	-	2005～06
D10	81 m^2 (9m×9m)	50 m^2	～2009
D11	-	-	
Total	1113 m^2	320 m^2	

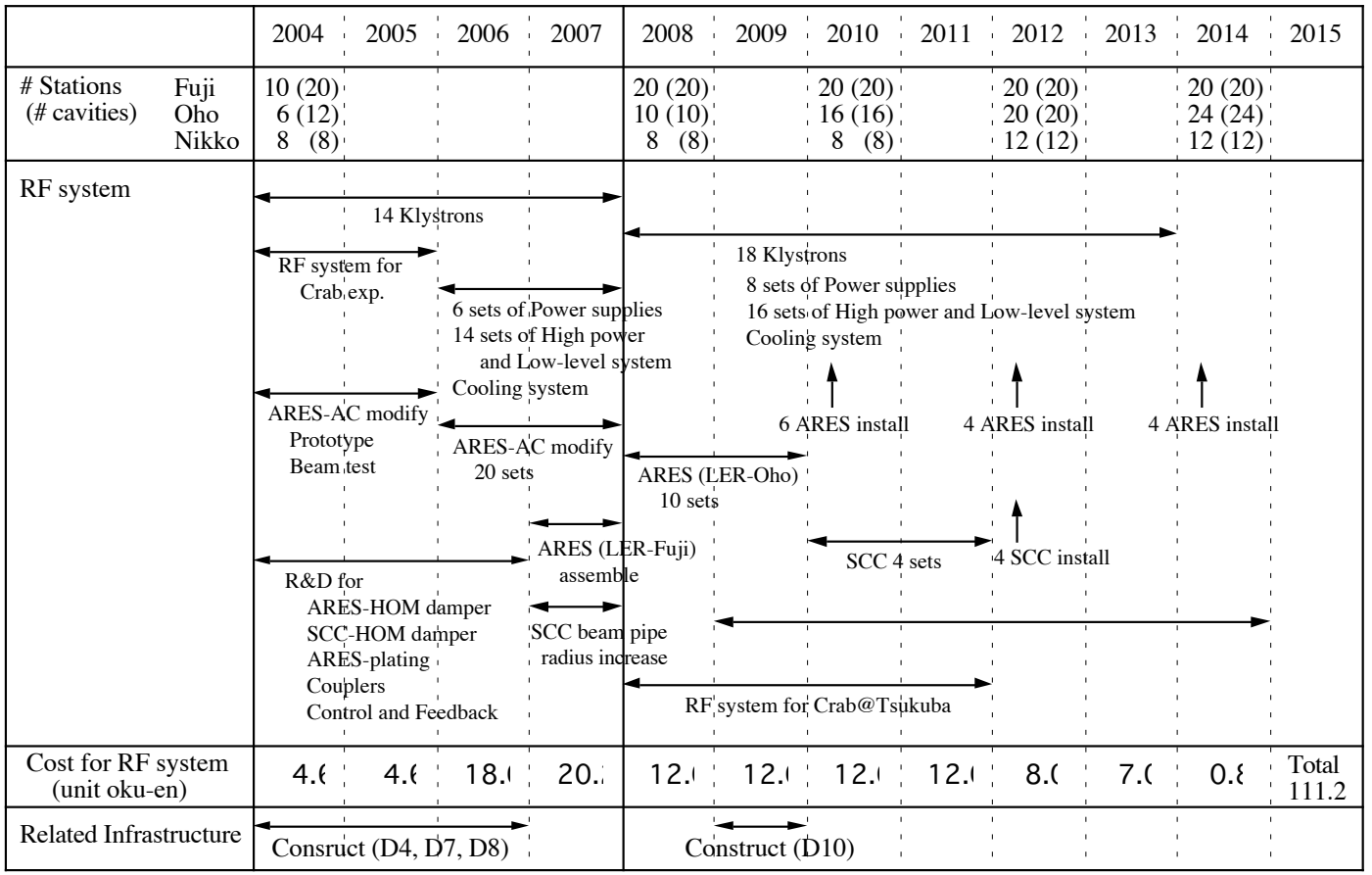
Construction plan

- **Before 2008**
  - **Construct 14 units of RF system**
    - **To change to 1 ARES/1 klystron configuration**
  - **2 RF stations for Crab crossing experiment @Nikko**
- **After 2008**
  - **Construct 18 units of RF system**
  - **Fabricate 10 more ARES's**
  - **Fabricate 4 SCC's**
  - **Construct RF system for Crab cavities**

Schedule

Super-KEKB Adiabatic Construction --- RF Group

2003. 9. 1
2003. 9. 5 revised
K. Akai



Cost estimation

- **Total cost = 111.2 Oku-yen, including**
  - **32 klystrons**
  - **15 power supplies**
  - **Evaporative cooling system for klystron collector**
  - **32 High-power and Low-level systems**
  - **20 existing ARES's to be modified**
  - **10 new ARES's for LER**
  - **4 additional SCC's for HER**
  - **RF system for Crab cavities**
  - **R&D and Beam tests**
- **Cost for related infrastructures such as buildings, electricity, cooling system are not included.**

RF system for Damping Ring

- **Base plan assumed**
  - **Same RF frequency as KEKB**
  - **Use ARES (full set)**
- **Construction**
  - **Fabricate a klystron and an ARES cavity.**
  - **An existing power supply (B-type) will be moved.**
  - **High-power and low-level system: partly new, partly reused.**
  - **Total cost is about 2.4 Oku-en. (Building is not included.)**

- **RF-related parameters**

Bunch charge	**2.5**	**nC**
Number of bunches	**4**	**(2x2)**
Circumference	**131.3**	**m**
Beam current	**23**	**mA**
Energy loss/turn	**0.073**	**MV**
RF frequency	**508.9**	**MHz**
RF voltage	**0.261**	**MV**
Wall dissipation	**42**	**kW**
Beam power	**1.7**	**kW**
Number of cavity	**1**	

Summary of SuperKEKB RF system_1

- **Base plan:**
  - **The existing RF system will be used as much as possible, with improvements as necessary.**
- **To suppress the CBI due to the accelerating mode:**
  - **LER-ARES will be modified to increase the stored energy.**
  - **The -1 mode damper will handle the growth time of 1 ms.**
- **CBI due to RF cavities:**
  - **Transverse modes can be suppressed by the present BbyB FB.**
  - **Longitudinal BbyB FB is required with a damping time of 4 ms.**
- **HOM dampers to absorbe a large power:**
  - **Performance limit of the present dampers will be tested.**
  - **A new damper may by necessary, particularly for the GBP damper.**

Summary of SuperKEKB RF system_2

- **Strengthening of RF power by a factor of 4.**
  - **Improvement of the couplers will continue to double the operating power.**
  - **The number of RF unit will be doubled.**
- **Crab cavity**
  - **A new crab cavity is proposed, which can be used at 10 A.**
  - **The design is completed. It has sufficient property for SuperKEKB.**

Impedance-related issues

Loss factor of LER

	KEKB @4mm in Design Report		Super-KEKB @3mm			
	Number of items	Loss factor (V/pC)	Number of items	Loss factor /item (V/pC)	Loss factor (V/pC)	Comment
ARES cavity	20	10.6	28	0.667	18.7	
Resistive-wall	3016 m	4.0	3016m	-	6.5	Copper
Photon Masks at arc	1000	4.6	800	1E-8	8E-6	ante-chamber
Pumping slots at arc	10x1800	0.37		-	0.0019	ante-chamber
Pumping slots @straight		+	800		+	
BPMs	4x400	0.79	4x400		+	
Masks at IP	1	0.08	1		+	pending
IR chamber	1	0.29	1		+	pending
Recomb. chambers	2	1.6	2		+	pending
Bellows	1000	2.5	800	4E-3	3.2	
Flange gap		+	800	1E-4	0.08	
Gate Valve		+	40	3.1E-3	0.12	
Feedback kickers		+			+	
Injection/Abort kickers		+			+	
Septum		+			+	
Movable masks		+	16	1	16	
HOM absorbers (RF end)		+	4	～0.5	～2	150φ
Tapers (RF end)		+	4	0.04	0.16	94⇔150φ
Tapers (others)		+	72	3E-3	0.22	
Total		25.7+			46.9+	tentative

(Suetsugu, Shibata, Stanic, Kageyama, Akai)